Elgaid, K. and McLelland, H. and Stanley, C.R. and Thayne, I.G. (2005) Low noise W-band MMMIC amplifier using 50 nm InP technology for millimeterwave receivers applications. In, *International Conference on Indium Phosphide and Related Materials, 8-12 May 2005*, pages pp. 523-525, Piscataway.

LOW NOISE W-BAND MMMIC AMPLIFIER USING 50nm InP TECHNOLOGY FOR MILLIMETERWAVE RECEIVERS APPLICATIONS

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Abstract
We report on W-band LNA (MMMICs) based around a 50nm InP-HEMTs with an f_T of 0.550THz. The LNA noise figure is 2.5dB and associated gain of 7.3 dB at 90GHz with a bandwidth of 24GHz.

I. INTRODUCTION

Although relatively low volume at present, a significant and growing high added value market exists for mm-wave imaging and sensing applications, the key component of which is the front-end low-noise amplifier in the receiver.

System sensitivity is ultimately determined by the performance of the front-end amplifier which should possess outstanding high frequency characteristics. The acknowledged device of choice for front end amplifier realisation is a short gate length, InP-based HEMT[1] such as the technology described in this paper.

While performance is a key merit for successful adoption of a technology, time-to-market is becoming an equally important contributor to market growth. To improve product time-to-market, a range of strategies, in particular array-base design are being adopted. Array-based design, which has been hugely successful in the digital field, has not been embraced by the microwave and mm-wave community to date due to perceptions of design, performance and process flow limitations arising from this approach.

The amplifiers reported in this work are realised using an array-based methodology in which a relatively sparse matrix of high performance 50nm gate length InP HEMTs is first defined on a grid optimised to enable the realisation of a range of mm-wave components. Following the identification of known good active devices by in-line DC and RF testing, the MMMIC's, in this case amplifiers, are completed by passive device realisation. This design concept and process flow is enabled by the low temperature nitride deposition technique used in this work [2,3].

The successful realisation of MMMIC's using the approach described in this work paves the way for further investigation, optimisation and ultimate incorporation of array-based design methodologies in the mm-wave arena.

II. RESULTS

A. 50 nm T_gate InP HEMTs

High performance 2finger, 50μm gate width 50nm T-gate length InP HEMTs 70% indium concentration in the channel were realised using an e-beam lithography UVIII/LOR/PMMA resist stack [4] and a selective wet gate recess etch.

DC characterisations were performed by probing the 50nm T-gate device using Cascade MicroTech on wafer RF probes and measuring the electrical traces using Agilent 4155 Semiconductor Parameter Analyser.

Figure 1 shows a typical DC output characteristic of a 2x50μm wide device, I_{dss} of 500 mA/mm exhibited by the device at a drain bias (V_{ds}) of 1.0 V, and a pinch-off voltage (V_p)of -0.6V. Figure 2 shows the transfer characteristics of a 2x50 μm wide 50nm T-gate device, peak extrinsic DC transconductance (g_m) of 1.24S/mm was achieved by the device.

On-wafer S-parameter measurements were performed from 0.04 to 60 GHz, using an Anritsu 360B Vector Network Analyser and Cascade MicroTech on-wafer RF probes. Calibration was performed using a Cascade Microtech Impedance Standard Substrate (ISS) and the LRRM technique. Fitting of the measured S-parameters to a standard lumped element equivalent circuit model was used to de-embed the coplanar waveguide feed lines. Figure 3 shows the results of this analysis of a 2x50 μm wide 50nm T-gate device, yielding an exceptionally high f_T of 550 GHz and f_{max} of 440 GHz. To our knowledge, this is the highest reported f_T and f_{max} for a 50nm T-gate.

Figure 4 shows the 2finger, 50 μm gate width 50nm T-gate length InP HEMTs noise parameters measured up to 26 GHz, the device showed a very low noise parameter of 0.87 dB and associated gain of 14 dB at 26 GHz with exceptionally high I_{ds} and g_m of 210 mA/mm and 1.04 s/mm respectively.

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B. *94 GHz Amplifier Response*

A reactively matched amplifier designed is used to enhance the noise performance. 50Ω/□ NiCr resistors and room temperature deposited ICP SiN MIM capacitors are used at the biasing circuits for stability. Co-planar waveguide (CPW) is used as a transmission media. Figure 5 shows the performance of the modelled and measured one-stage w-band amplifier from 250MHz to 110GHz, measurements were performed using HP8510 Vector Network Analyser and on-wafer probes. The unconditionally stable single stage designed amplifier exhibits a gain of ~7 dB and a return loss of better than -5 dB across a bandwidth of 24 GHz from 71 GHz to 95 GHz. The biased operating point of the amplifier is V_{ds} of 0.8V and V_{gs} of -0.2Vpoint, with an output current of 23 mA. The measured performance is very well in agreement with the model. Figure 6 shows the MMMIC LNA noise figure measurements from 75GHz to 100GHz, the MMMIC LNA exhibits an excellent performance noise figure of 2.5 dB with associated gain of 7.3 dB at 90 GHz, the noise parameters of the MMMIC LNA are well behaved across the designed bandwidth

III. CONCLUSIONS

In this work we have demonstrated a low noise high performance w-band MMMIC LNA baed on a 50 nm T-gate 70% indium concentration in the channel InP HEMTs. The Performance of the realised device showed an excellent performance merits including f_T of 550GHz and f_{max} of 440GHz, g_m of 1240ms/mm and I_{dss} of higher than 500mA/mm. Noise parameter of 0.87 and associated gain of 14dB have been achieved at 26GHz. These devices are used for MMMIC realisation by integration with Metal Insulator Metal (MIM) capacitors formed from SiN deposited by ICP-CVD at room temperature. In comparison with existing 300°C PECVD SiN processes, the new approach offers reduced thermal budget and therefore the flexibility to realise all passive elements after active devices have been completed, leading to "sea-of-gates" array-based design methodologies for mm-wave applications. Using this approach, a 94GHz MMMIC one-stage amplifier with a gain of ~7dB and a return loss of better than –5dB across a bandwidth of 24GHz has been designed and fabricated and measured. The model and the measured performance are in agreement. Low noise figure of 2.5dB and associated gain of 7.3dB for the MMMIC LNA have been achieved at 90GHz, the noise parameters of the MMMIC LNA is well behaved across the designed bandwidth.

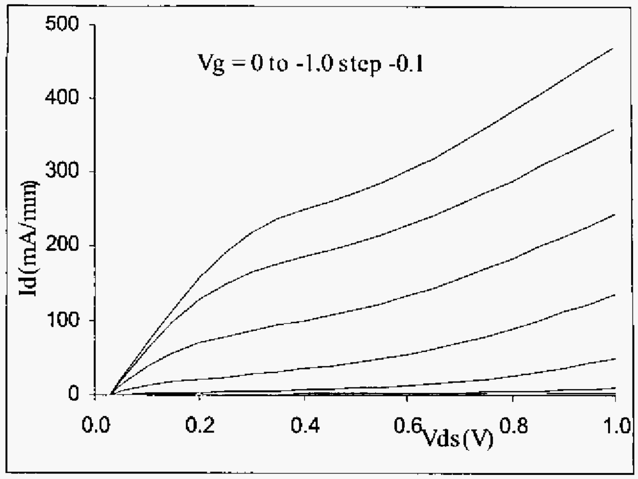

Fig. 1. Output characteristics of a 2 finger 50 μm gate width 50 nm gate length T-gate InP-HEMT, showing I_{dss} of 500mA/mm. Device was measured at V_{ds} up 1.0 V and V_{gs} from 0V to -0.6 V in -0.1 V steps, pinch-off voltage of -0.6V.

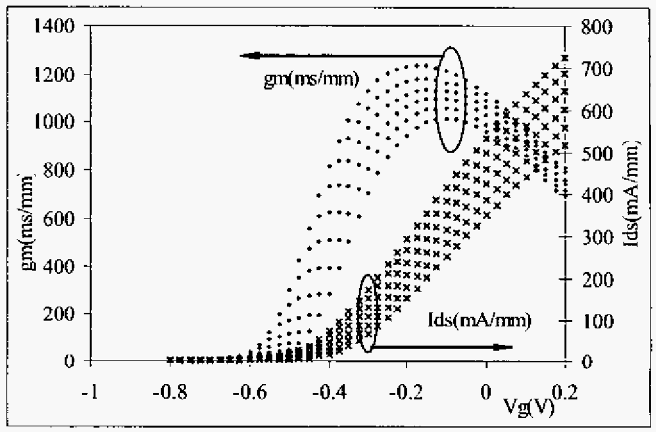

Fig. 2. Transfer characteristics of a 2 finger 50 μm gate width 50nm gate length T-gate InP-HEMT, a peak transconductance (g_m) of 1.24 /mm was obtained., V_{ds} measured from 1.2V to 0.7 V in -0.1 V steps.

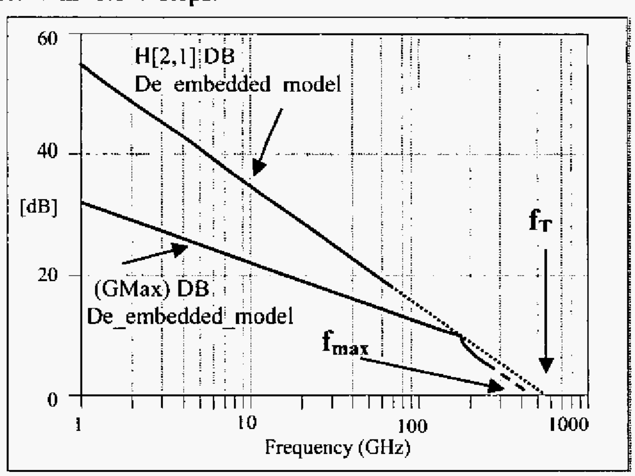

Fig. 3. RF performance of a 2-finger 50μm gate width with a 50nm gate length T-gate InP-HEMT, de-embeded model, the device showed a superior f_T of 550GHz and f_{max} of 440GHz.

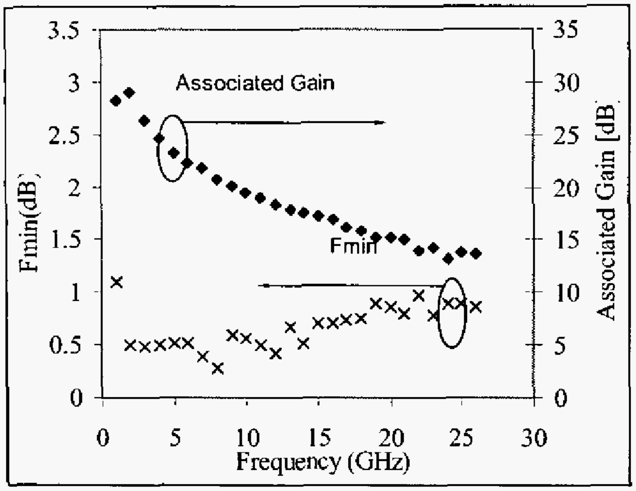

Fig. 4. Noise Parameters of a 2-finger 50μm gate width with a 50nm gate length T-gate InP-HEMT, low noise parameter of 0.87dB and associated gain of 14dB at 26GHz with exceptionally high Ids of 210mA/mm and a gm of 1040ms/mm.

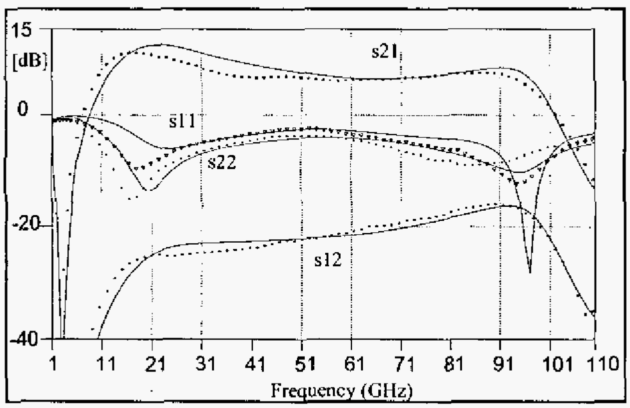

Fig. 5. Model and measured (doted) response of a W-Band one-stage MMMIC amplifier, measurements were conducted in the frequency range from 250MHz to 110GHz. The unconditionally stable single stage designed amplifier exhibits a gain of ~7dB and a return loss of better than -5dB across a bandwidth of 24GHz from 71GHz to 95GHz.

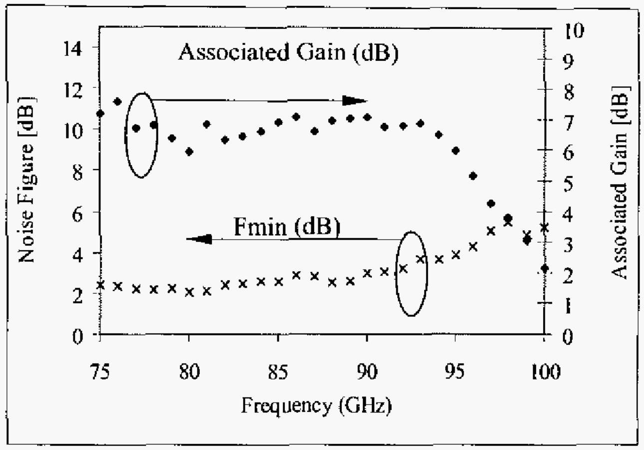

Fig. 6. Noise figure measurements from 75GHz to 100GHz, the MMMIC LNA exhibits a high performance noise figure of 2.5dB and associated gain of 7.3 dB at 90GHz, the noise parameters of the LNA is well behaved across the designed bandwidth.

ACKNOWLEDGEMENTS

This work was supported by the UK Engineering and Physical Sciences Research Council.

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